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Dated 11 December 2000

Patents Form 1/77

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27SEP99 E479625-1 D03081
P01/7700 0.00 - 9922761.3

THE PATENT OFFICE
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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
Newport
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1. Your reference — 99PAT025/1274MJB99

2. Patent application number *(The Patent Office will fill in this part)* — **9922761.3** — 27 SEP 1999

3. Full name, address and postcode of the or of each applicant *(underline all surnames)* — SENTEC LIMITED
TERRINGTON HOUSE
13-15 HILLS ROAD
CAMBRIDGE CB2 1GE

Patents ADP number *(if you know it)* — 7353733002

If the applicant is a corporate body, give the country/state of its incorporation — ENGLAND

4. Title of the invention — FIRE DETECTION ALGORITHM

5. Name of your agent *(if you have one)* — c/o ANDREW HOWE
SENTEC LTD
(as above)

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

Patents ADP number *(if you know it)*

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d)) — YES

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	0
Description	19 PAGES
Claim(s)	0
Abstract	0
Drawing(s)	3 PAGES

10. If you are also filing any of the following, state how many against each item.

Priority documents	0
Translations of priority documents	0
Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*	2 PAGES
Request for preliminary examination and search *(Patents Form 9/77)*	0
Request for substantive examination *(Patents Form 10/77)*	0
Any other documents *(please specify)*	0

11. I/We request the grant of a patent on the basis of this application.

Signature

Date 27 ~~SEP~~ SEP 99

12. Name and daytime telephone number of person to contact in the United Kingdom ANDREW HOWE 01223 303800

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Notes

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b) *Write your answers in capital letters using black ink or you may type them.*

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d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

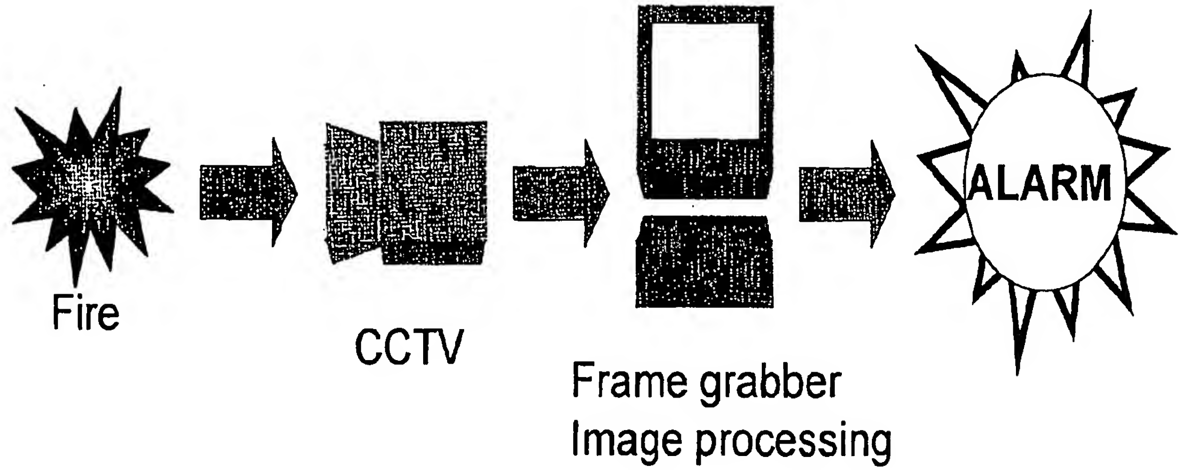
e) *Once you have filled in the form you must remember to sign and date it.*

f) *For details of the fee and ways to pay please contact the Patent Office.*

Fire Detection Algorithms

Sentec Limited
Terrington House
Cambridge

Brief



- Detect fires filmed by CCTV systems
- Primarily petrochemical/refinery environment
- Could be other environments
- Use standard PC, frame grabber and image processing software

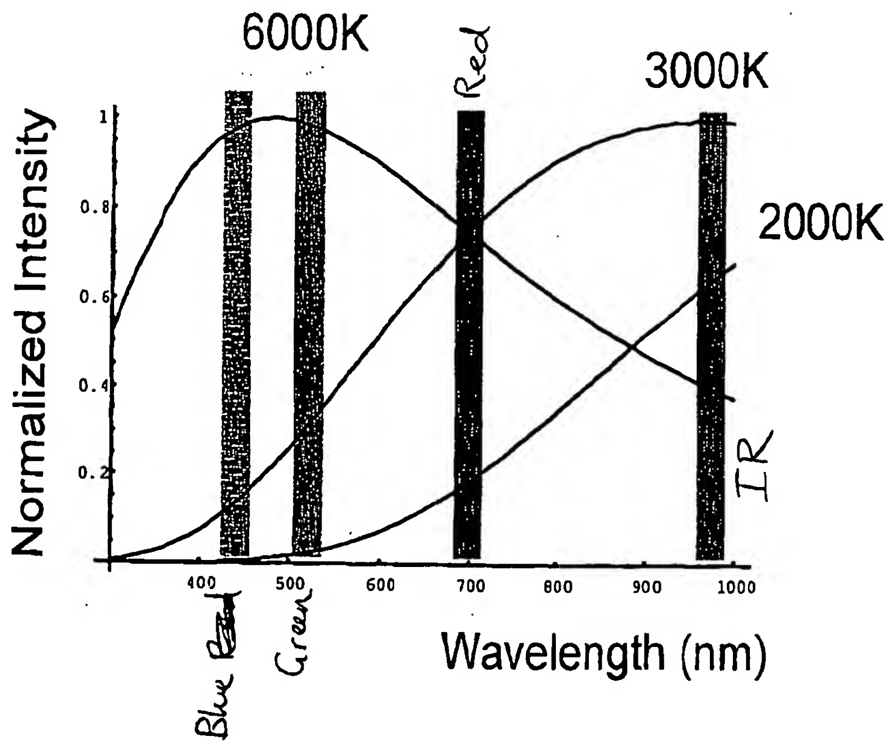
Development Environment

- PC using 'Scion Image' processing software.
- Compatible Scion LG-3 card.
- Detection algorithm written in 'Image' macro language

Algorithm Overview

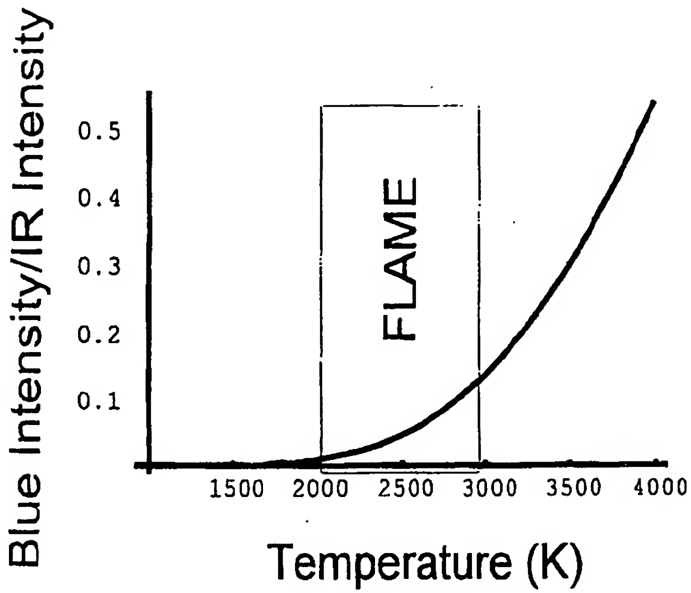
- Pre-filtering
- Image processing
- Image analysis
- Geometric analysis
- Statistics

Pre-filtering: Blackbody Radiation



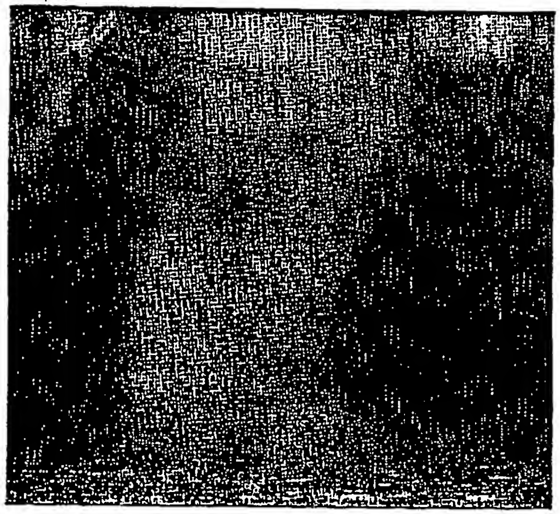
- Hot objects emit light in a characteristic blackbody curve
- Petrochemical flames occur between 2000K and 3000K
- Can measure the ratio between different wavelengths and use as a filter

Pre-filtering: Blackbody Example



- Measure ratio between selected wavelengths and apply blackbody formula.
- Adds to selectivity of system.
- Requires colour or IR camera or filters.
- CCTV sensitive up to 900nm.

Pre-filtering: Blackbody Example

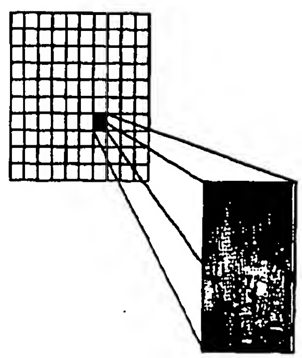


Colour image of fire

Detection using R and B channels.

IR gives greater selectivity.

Selection of 1% Screen Area



- Separate screen into 10x10 grid.
- Can do this with simple region of interest selection.
- Monitor each 32x20 frame individually.
- Increases computing efficiency.

Pre-filtering: Unwanted Objects

- Some objects e.g. smoke plumes, controlled fire will be indistinguishable from fire.
- Can avoid detection by introducing blind spot into system.
- Simplest way to do this is with a bitmap mask.

Image processing Level 1:
Accounting for Gradual Changes

- If scene is outdoor, we expect gradual variations such as nightfall or weather changes
- Use a time averaging filter to ignore slowly changing features
- Typically use P = 0.05-0.1

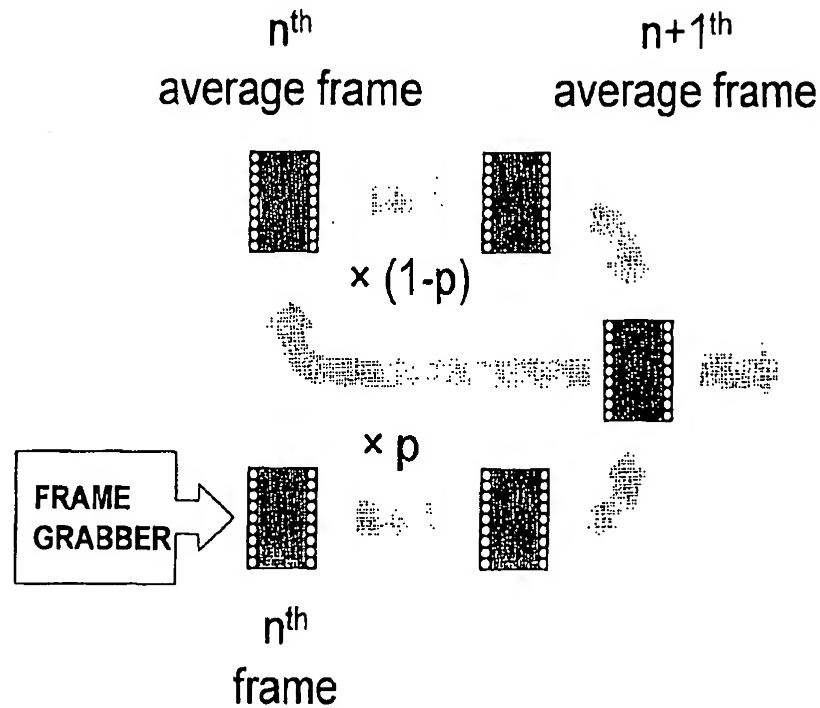


Image processing Level 2:
Finding changes

- Rapid changes in the image can be detected by assessing the difference between the current frame and the current averaged frame

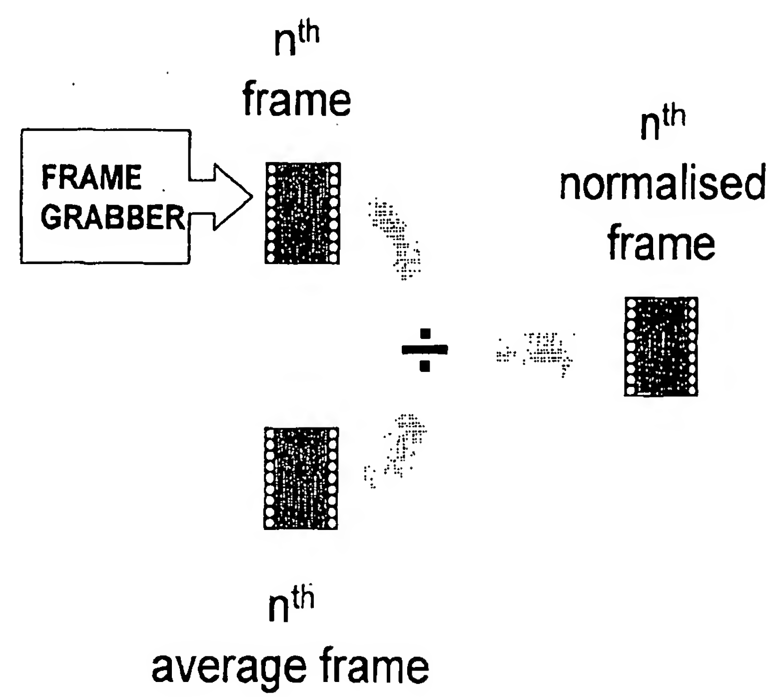


Image processing Level 3:
Finding movement

- Movement in the image can be found by looking at the differences between successive normalised frames

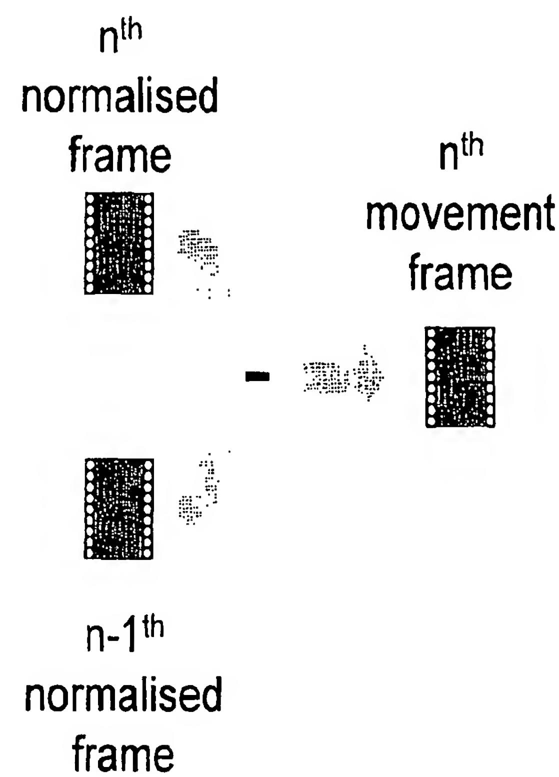


Image processing Level 4:
Thresholding

- Thresholding isolates real movement from variations due to lighting, shadows and noise. The result is a movement map

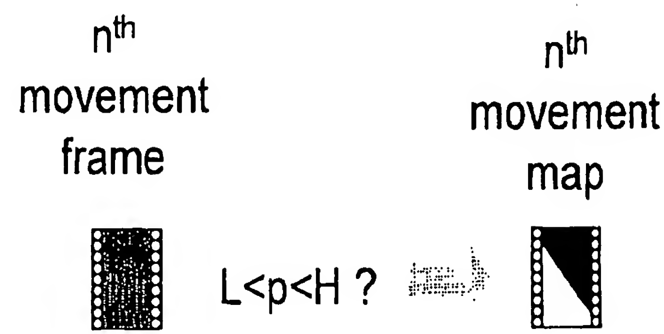


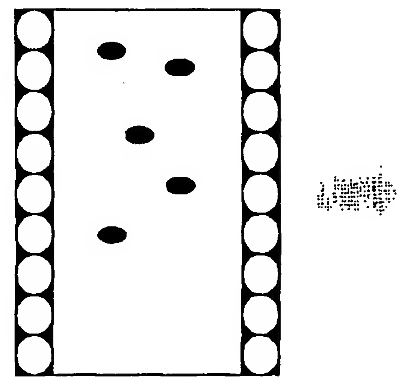
Image Analysis:

- Particle analysis of the movement map separates solid objects from 'fluid' objects such as flame and smoke
- Analysis results in 3 parameters:

  N - the number of particles

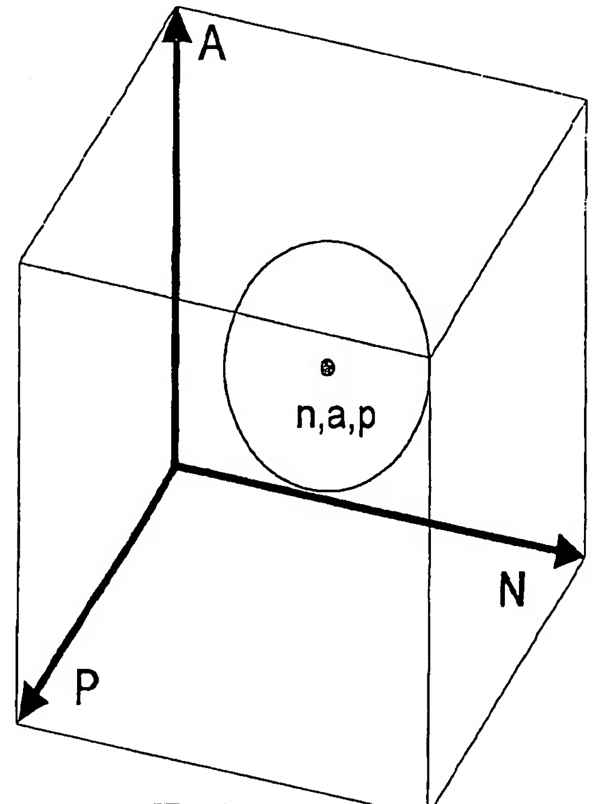
  A - their area

  P - their perimeter



Geometric Analysis:

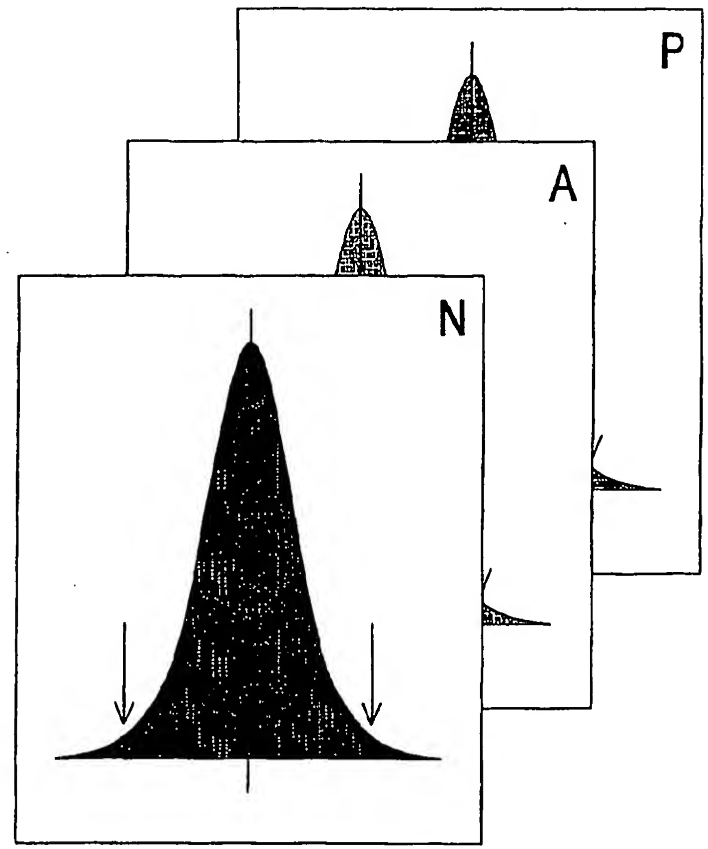
- Repeatable combinations of N,A and P are characteristic for each of flame / smoke etc.
- Apply simple geometric rule in orthogonal space to assess whether current values fall within standard volumes determined by calibration



$$\sqrt{(N-n)^2+(A-a)^2+(P-p)^2}<k?$$

Statistics:

- Additional confidence can be gained by applying statistical analysis to the results of particle analysis
- Flame and smoke will exhibit characteristic values for statistical parameters such as the variance and standard deviation of N, A and P
- The distributions will be gaussian



Algorithm Summary

- Pre-filtering - spectral selection
- Image processing - generate movement map

for each pixel:

$$\boxed{m(p) = \left(L < \left[\frac{p - p \cdot z^{-1}}{k \cdot p + (1-k) \cdot p \cdot z^{-1}} \right] < H \right)}$$

(5 flops, 2 ints, 2 memories per pixel)

- Image analysis - generate per-frame N,A & P
- Geometric analysis - match N,A & P to calibration
- Statistics - check N,A & P over time

Next Steps

- Use collection of real fire footage to establish calibration parameters for different classes of fire and smoke
- Investigate suitable hardware
- Optimise algorithm for hardware architecture
- Write Code

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Fire Attributes

We have identified a list of characteristics which video images of fires possess. Together, these can be used to determine whether a fire is occurring inside the frame of interest.

(1) Fires emit light in a well-defined 'blackbody' distribution.

(2) The shape of a fire changes as a function of time.

(3) The shape of a fire has a complicated 'fractal' structure.

(4) The individual tongues of flame propagate with a high velocity.

(5) Convection of heat flow causes fires to move in a general upwardly direction.

(6) Smoke is generated by fire.

Searching for these properties together it is possible to create a filter which excludes events which are not fire based. For example, a sodium street light has similar spectral characteristics to that of a petrochemical flame, but it does not change shape as a function of time or have a complex structure.

In practice, we analyze only moving components in our images by examining the difference between subsequent frames. The total perimeter, area, position and density of the resulting patterns can then be combined with one another to generate quantitative estimates of the attributes listed above. To first order it is possible to obtain an approximate estimate of the probability of a fire occurring by adding these parameters together for each difference frame.

More precise functions can be developed, but in order to achieve this most efficiently we need to tailor our detection system to petrochemical fire footage.

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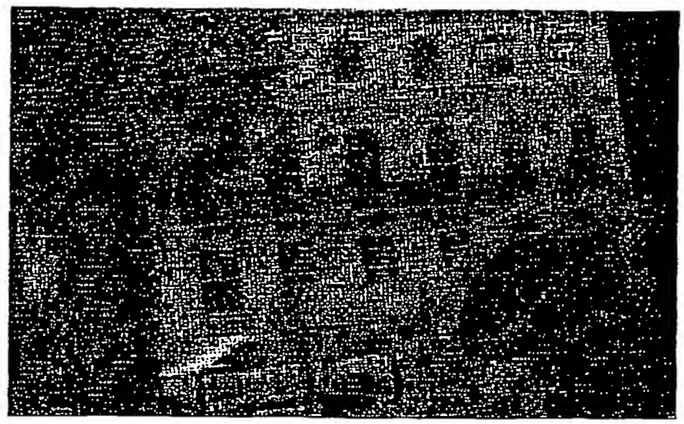
Examples



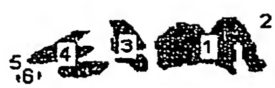


Image of moving car (upper) and analyzed image (lower).

Particles are densely situated relative to their area, and only a small number are visible.

No fire threat indicated.

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Examples

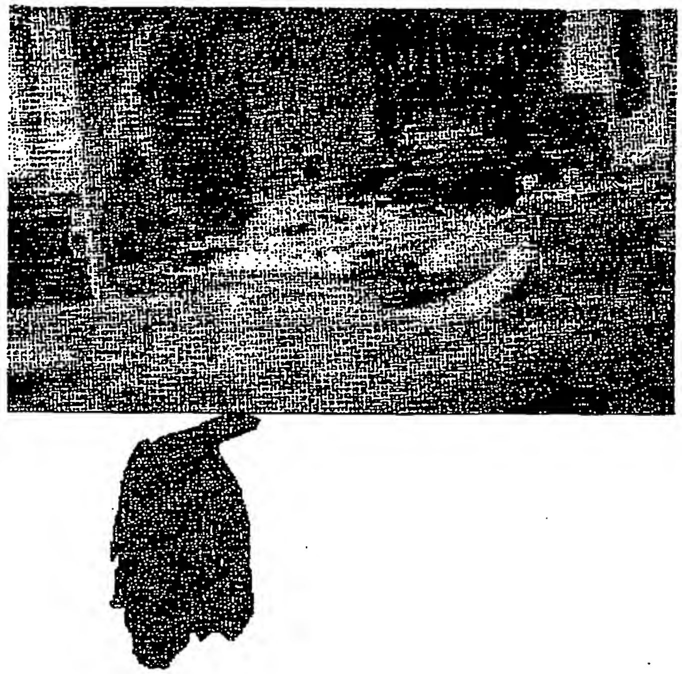

Image of person walking past camera.

Only one particle with low perimeter/area ratio.

No fire threat indicated.

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Examples

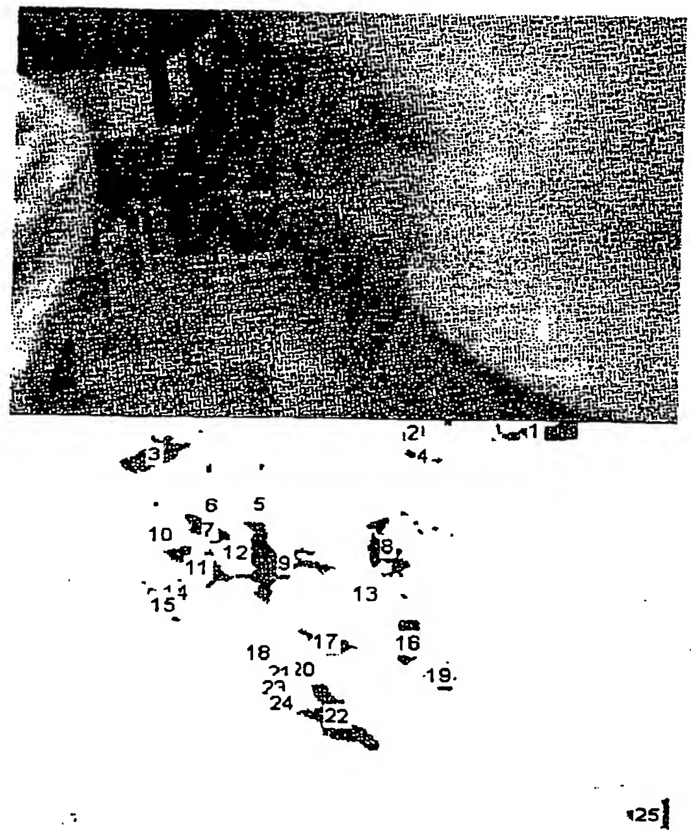

Image of an in-house fire.

Many particles = 25, large perimeter area ratio allows easy detection.

Fire threat.

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